17.—Identity of the Hart Range and Boxhole iron meteorites

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Manuscript received 17 April 1973; accepted 17 July 1973.

Abstract

A detailed examination of the geographical location, microstructure and chemical composition of the Hart Range and Boxhole iron meteorites has established that they are a paired find. It is not certain whether human transport or atmospheric break-up is responsible for the separate locations of the two meteorites, though it is probable that the Hart Range meteorite was transported by human agency. It is recommended that the name Hart Range be deleted from future meteorite catalogues. Similar studies of the iron meteorites associated with the Henbury and Wolf Creek craters have shown that all three craters were formed by separate events, thus substantiating the conclusion of Wasson (1967,a).

Introduction

In 1937 a meteorite crater was recognised on Boxhole Station, which is 185 Km north-east of Alice Springs in Central Australia at latitude 22° 37′ S and longitude 135° 12′ E. A number of siderites were found in the immediate vicinity of the crater, and they proved to be medium octahedrites, (Madigan and Alderman, 1940). The Boxhole meteorites resembled the siderites associated with the Henbury meteorite crater (Alderman 1932 a, 1932 b). The Henbury crater, which was found in 1931, is located some 121 Km south-west of Alice Springs near Henbury Station in Central Australia, at latitude 24° 34′ S and longitude 133° 10′ E.

The Boxhole and Henbury craters therefore lie about 300 Km apart, and this is far greater than the linear dimensions of the largest well-documented meteorite shower, the Allende chondrite, which is scattered over an ellipse 50 Km long and approximately 300 Km^2 in area (Clarke et al. 1970). A recent study by de Laeter et al (1973) of two Western Australian siderites, Gosnells and Mt. Dooling, has shown conclusively that they are a paired fall, although they were found 400 Km apart. Although it was concluded that the Gosnells meteorite was probably transported by human agency the evidence was not definitive, and the opportunity of examining the relationship between meteorites from two locations of undisputed origin was therefore welcomed.

Wasson (1967, a) examined the possibility that the Boxhole and Henbury craters had a common origin, and also investigated the medium octahedrites associated with the Wolf Creek crater. The Wolf Creek crater, which was discovered in 1947 (Taylor, 1965), is situated some 850 Km north-west of the other two craters at latitude 19° 11′ S and longitude 127° 48′ E. Wasson (1967 a) studied the chemical composition of representative samples of the irons associated with the 3 craters and concluded that they were each formed by a separate event.

In May 1944 Mr. J. S. Foxall presented the Geological Survey of Western Australia with a 608 g iron meteorite. It was obviously a fragment of another meteorite, and the broken surface revealed a definite octahedrite structure. The meteorite was named Hart Range by McCall and de Laeter (1965), who classified it as a medium octahedrite. The exact location of the find was not known, except that it came from the Harts Range area in Central Australia, latitude 23° S and longitude 135° E. The locations of the meteorites are shown in Figure 1, whilst Figure 2 is a photograph of the Hart Range meteorite, and clearly reveals the octahedrite structure where it has broken off the main mass.

Dr. B. Mason of the Smithsonian Institution, Washington D.C., U.S.A. suggested that the Hart Range meteorite was in fact part of the Boxhole fall. It was therefore decided to test this hypothesis by examining the microstructure and chemical composition of the two meteorites. It was also decided to independently assess the conclusions of Wasson (1967, a) with respect to the Boxhole, Henbury and Wolf Creek meteorites.

Structure

A sample of each meteorite was obtained from the collection of the Western Australian Museum, and a suitable face cut on each of the 4 meteorite specimens. After polishing, the smoothed surfaces were etched with dilute nitric acid to reveal the Widmanstatten pattern. Photomicrographs of the etched surfaces were taken and two of these, Hart Range and Boxhole, are reproduced as Figure 3a and 3b respectively.

The structures revealed in the micrographs are remarkably uniform. The main constituent is the nickel-iron alloy kamacite, in regular well-defined plates arranged parallel to the faces of a regular octahedron. The width of the plates vary from 0.75 mm to 1.25 mm with an average width of 1 mm. The two meteorites should therefore be classified as medium octahedrites on Buchwald's classification (see Wasson, 1970). The similarity of the Widmanstatten patterns imply that the samples of Hart Range and Boxhole could be pieces of the same meteorite.

The Widmanstatten pattern for Henbury has a kamacite band width which varies from 0.6 mm to 0.9 mm, with an average width of 0.75 mm. Thus although Henbury is still classified as a medium octahedrite it has a narrower kamacite band width than Boxhole or Hart Range, though

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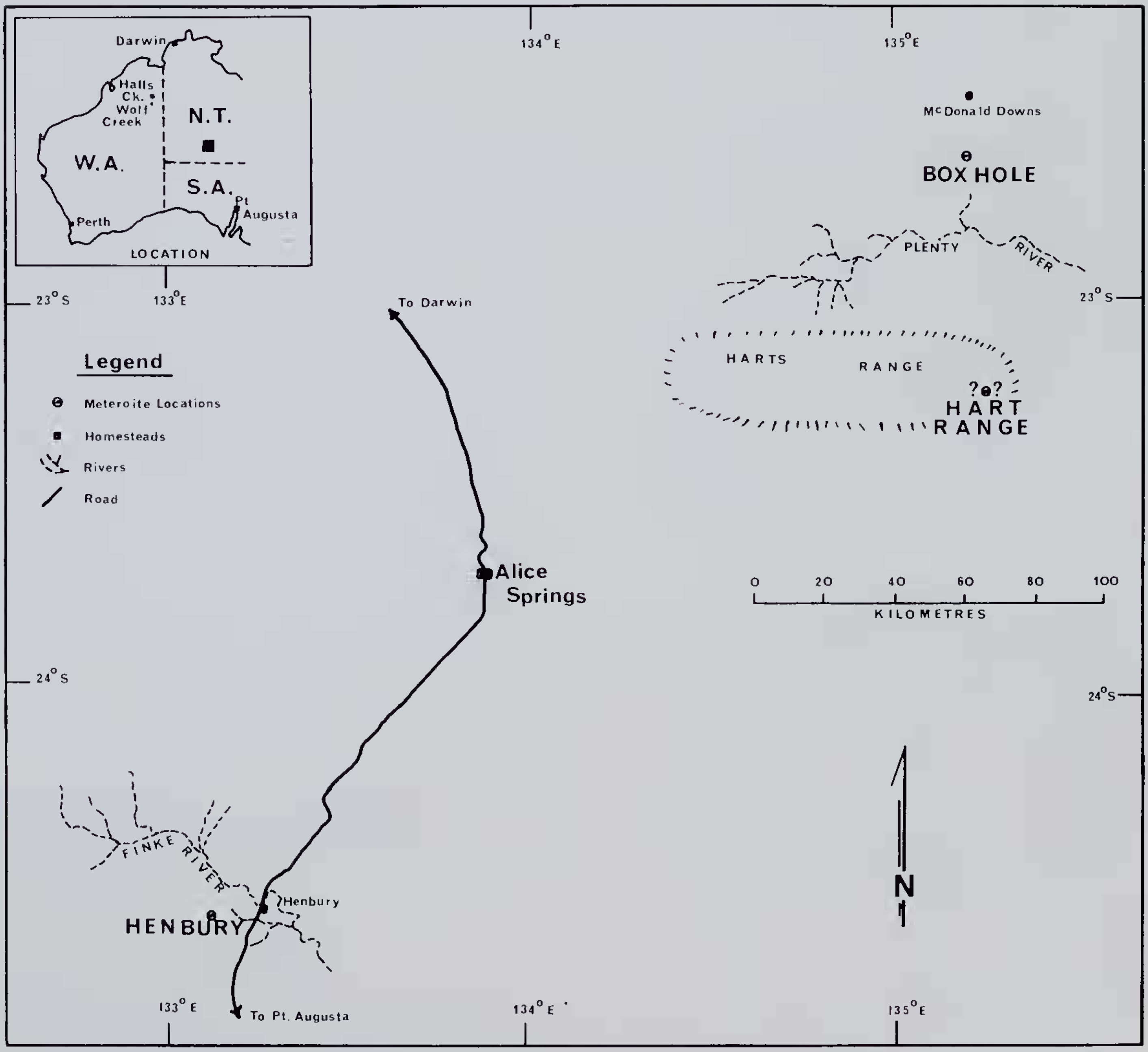


Figure 1.—Location of the Boxhole, Henbury and Wolf Creek craters.

the difference is probably not significant. Alderman (1932 b) states that the average kamacite band width is 1 mm in some specimens and up to 1.5 mm in others. Wolf Creek has an average kamacite band width of 0.9 mm. Polished and etched sections of this meteorite have been illustrated by Taylor (1965).

Chemical composition

J. T. Wasson and his associates have carried out a series of investigations during the past 6 years to elucidate the chemical classification of iron meteorites, primarily in terms of their gallium-germanium grouping (Wasson, 1967 b; Wasson and Kimberlin, 1967; Wasson, 1969; Wasson, 1970; Wasson and Schaudy, 1971; Schaudy et al, 1972). On the basis of accurate analytical data on some 450 iron meteorites, eleven chemical groups have been defined.

A considerable amount of analytical data is available for Henbury and Boxhole, whereas Wolf Creek has only been analysed by Taylor (1965) and Wasson (1967 a). As far as can be ascertained Hart Range has never been analysed at all.

In order to classify the four meteorites into one of the eleven chemical groups defined by Wasson and his associates, it was decided to analyse the four meteorite samples non-destructively for nickel, gallium and germanium by X-Ray fluorescence spectrometry. The cobalt abundance was also determined since, together with iron and nickel, it is one of the major constituents of iron meteorites.

A Siemen's SRS-1 spectrometer equipped with a molybdenum tube, a lithium fluoride crystal and a scintillation detector was used for the analyses. A flat, highly polished surface approxi-

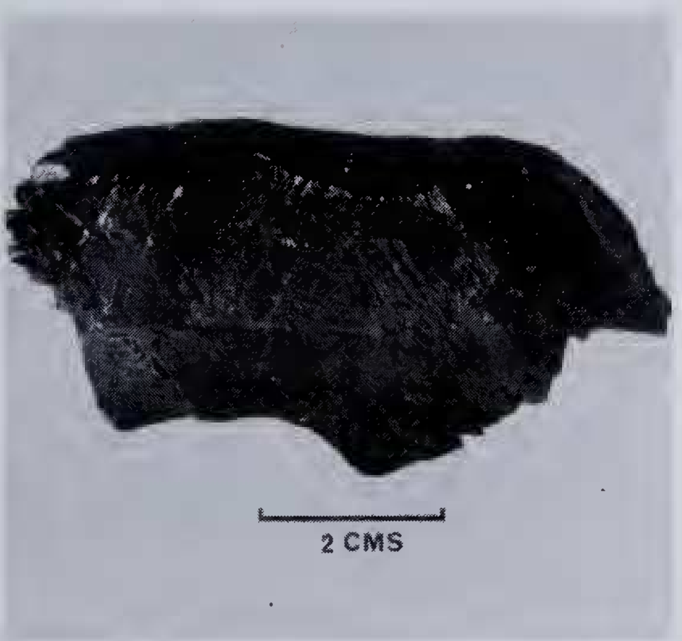
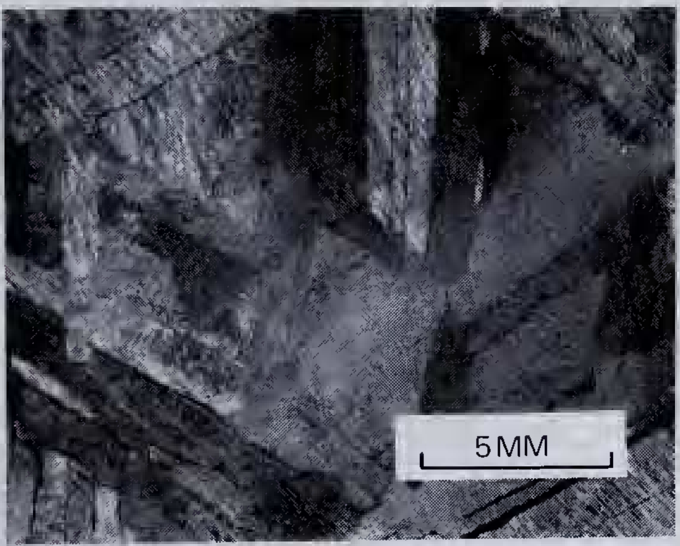


Figure 2.—The Hart Range octahedrite.



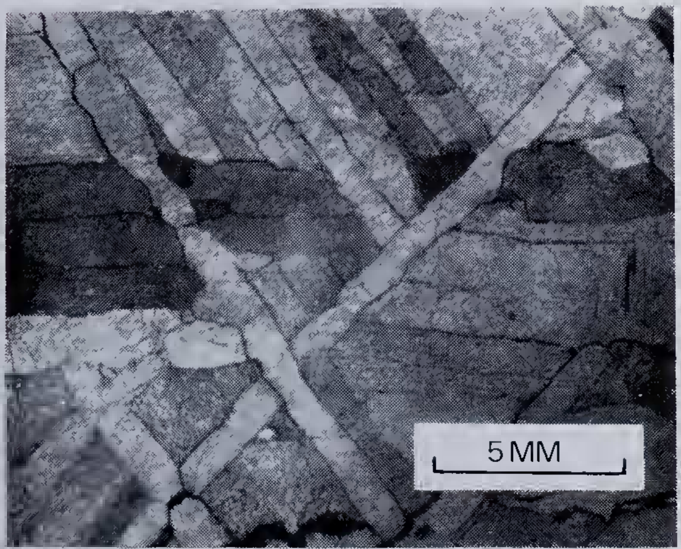


Figure 3.—Polished and etched sections of (above) Hart Range and (below) Boxhole siderites.

mately 1.25 cm in diameter was prepared. This surface was exposed to the X-Ray beam, and peak and background readings were taken for each of the four elements. The spectrometer was calibrated for each element by standard alloys, and from a number of siderites with well established compositions. Full details of the X-ray spectrometry are given by Thomas and de Laeter (1972).

The results of the determinations for the four elements are given in Table 1. The errors quoted with the values have been evaluated on the basis of counting statistics and calibration uncertainties, and are expressed as standard deviations. The analytical work of other authors for these elements have also been listed in Table 1. A number of analyses for Henbury have been omitted from Table 1 since they have been made on mislabelled specimens, (see Smales, 1967).

An examination of the data listed in Table 1 shows that within experimental error, the abundance of cobalt, nickel, gallium and germanium in Boxhole and Hart Range are identical. This supports the structural evidence that Hart Range and Boxhole are pieces of the same meteorite.

Wasson and Kimberlin (1967) define Chemical Group IIIA as having nickel values ranging from 7.4% to 8.7%, germanium values in the range 33 to 46 ppm and a range in gallium from 18 to 22 ppm. In addition the gallium and germanium are positively correlated with nickel. The III A irons are also characterised by regular kamacite bands of average width 1 mm in thickness, and by the paucity of inclusions. Boxhole and Hart Range can therefore be classified as Group III A meteorites.

The analytical data for Henbury also classifies it as a member of Chemical Group III A, whereas the high nickel value of Wolf Creek enables it to be classified as a Group III B meteorite. Group III B is defined by Wasson and Kimberlin (1967) as having a range in nickel, germanium and gallium of 9.2 to 10.7%, 28 to 40 ppm and 16 to 20 ppm respectively. Wolf Creek is therefore unrelated to the Henbury or Boxhole craters and was clearly formed by a separate event.

Henbury is much more difficult to distinguish from Boxhole. Apart from the fact that they are both Group III A meteorites, their abundances of cobalt, gallium and germanium are identical within the limits imposed by experimental error. One has also to note that sample inhomogeneities occur within the same meteorite and it is therefore not surprising to find small variations in elemental abundance between samples from the same meteorite fall. This is particularly true for large meteorite falls, and certainly for those whose impact has produced craters. Wasson (1967 c) has analysed numerous siderite samples from the Canyon Diablo crater and has found that the nickel concentrations range from 7.0 to 8.2% whereas the range in germanium and gallium on the same samples is from 317-332 ppm and 79-83 ppm respectively.

The X-Ray fluorescence spectrometry data of the present study as listed in Table 1 indicates that the nickel content of Boxhole and Hart

Table 1

Analytical data for the four meteorites

Sample*	Cobalt (%)	Nickel (%)	Gallium (p.p.m.)	Germanium (p.p.m.)	Reference
Boxhole 2/1872	0·48 ± 0·005	7·59 ± 0·02	18 ± 2	38 ± 4	1
	0·48	7·66	....	....	2
	....	7·64	18·1	37·2	3
	....	7·68	18·1	37·2	4
	0·50	7·72	13·0	31·0	5
	0·41	7·67	....	....	6
	....	7·1†	....	....	7
Hart Range 2/2851	0·48 ± 0·005	7·60 ± 0·02	20 ± 2	38 ± 4	1
Henbury	0·47 ± 0·005	7·44 ± 0·02	18 ± 2	35 ± 4	1
	....	....	18·8	....	8
	0·47	7·62	....	....	2
	....	7·44	17·4	34·2	3
	....	7·47	17·4	34·2	4
	....	....	15·0	36·0	9
	0·70	7·59	17·2	....	10
	0·30	7·40	....	....	11
	0·37	7·54	....	....	12
	....	6·7†	....	....	7
Wolf Creek 12680	0·50 ± 0·005	9·38 ± 0·02	22 ± 2	42 ± 4	1
	....	9·23	18·4	37·3	3
	0·4	8·6	....	....	13

* Sample numbers refer to the W.A. Museum Collection.
† Kamacite phase only

References
1 This Work
2 Lewis & Moore (1971)
3 Wasson (1967 a)
4 Wasson & Kimberlin (1967)
5 Lovering et al. (1957)
6 Madigan and Alderman (1940)
7 Reed (1969)
8 de Laeter (1972)
9 Smales et al. (1967)
10 Goldberg et al. (1951)
11 Spencer (1933)
12 Alderman (1932 b)
13 Taylor (1965)

Range is significantly different from its abundance in Henbury. However the stated errors do not take into account sample inhomogeneities. Some recent work by de Laeter (1973) on the Youndegin meteorite shower, using identical analytical procedures as in this paper, give a range of nickel values from 6.47% to 6.92% over 10 meteorite samples, which are believed to be from the one meteorite fall. Thus under the circumstances, the nickel value of 7.44% for Henbury as compared to 7.59% for Boxhole, cannot conclusively differentiate the two meteorites as unique events. The nickel values obtained by Wasson (1967, a) and Wasson and Kimberlin (1967) using atomic absorption spectroscopy confirm the data obtained in the present study, and in fact all the nickel values for Boxhole listed in Table 1 show a tight range from 7.59% to 7.72%, with an average value of 7.65%. The nickel values for Henbury on the other hand range from 7.40% to 7.62% with an average of 7.50%. The data implies that the nickel value of Boxhole is significantly higher than for Henbury, and this conclusion is strengthened by the kamacite values of Reed (1969). Reed also found that the rhabdite abundance in Boxhole was significantly greater than in Henbury. However the interpretation of the nickel data is not definitive, and it was therefore decided to examine additional evidence in the hope of confirming the uniqueness of the Boxhole and Henbury craters.

Table 2 lists some additional analytical data for the Boxhole and Henbury siderites. The quoted errors represent the standard deviations of the respective measurements. Much of the data does not allow any definitive conclusions to be drawn, but this is to be expected since both are medium octahedrites and members of the same chemical group. It is therefore likely that the two meteorites have a similar genetic origin (Wasson and Kimberlin, 1967).

The phosphorus values determined on the kamacite phase by Reed (1969) are different, but not definitively so, although the bulk phosphorus values are approximately the same. The carbon values of Lewis and Moore (1971) are markedly

Table 2

Analytical data for Boxhole and Henbury meteorites

Element	Boxhole	Reference	Henbury	Reference
Phosphorus	0·08%	1	0·08%	4
	0·11%	2	0·09%	2
	*1020 ± 180 p.p.m.	3	*840 ± 80 p.p.m.	3
Carbon	....		0·13%	4
	0·013%	2	0·007%	2
Iridium	9·1 ± 0·5 p.p.m.	5	15 ± 0·8 p.p.m.	5
	....		12 ± 0·6 p.p.m.	6
	....		14 ± 0·3 p.p.m.	7
Copper	133 ± 16 p.p.m.	8	156 ± 16 p.p.m.	9
	....		180 ± 5 p.p.m.	7
Chromium	62 ± 7 p.p.m.	8	58 ± 6 p.p.m.	9
Zinc	....		2·04 ± 0·02 p.p.m.	10
	1·9 ± 0·05 p.p.m.	11	1·2 ± 0·05 p.p.m.	11
	....		< 1 p.p.m.	9
Cadmium	7 + 2 p.p.b.	11	8 ± 2 p.p.b.	11

* Kamacite phase only

References

1 Madigan & Alderman (1940)
2 Lewis & Moore (1971)
3 Reed (1969)
4 Alderman (1932 b)
5 Wasson (1967 a)
6 Wasson & Kimberlin (1967)
7 Cobb (1967)
8 Lovering et al. (1957)
9 Smales et al. (1967)
10 Rosman (1972)
11 This work

different, but one can not be sure that the difference in the values have not been caused by varying amounts of cohenite in the particular samples analysed. The chromium and cadmium values are also identical within experimental error.

A careful evaluation of the iridium, copper and zinc data show that the values are significantly different for the two meteorites in terms of the experimental errors. This supports the primary nickel abundance data, and reinforces the hypothesis that Boxhole and Henbury are distinct and separate meteorites.

The cadmium and zinc analyses carried out as part of this study have been determined by the stable isotope dilution technique using solid source mass spectrometry. Experimental details will be published elsewhere (Rosman and de Laeter, 1974).

Conclusions

The evidence set out in this paper establishes the fact that the Hart Range and Boxhole meteorites are a paired find. Although the Hart Range meteorite is reported to have been found some 60 Km from the Boxhole crater, the information is inconclusive, and the specimen may well have been found closer to Boxhole than is indicated in Figure 1, or have been transported by human agency to Harts Range from the Boxhole crater area. The microstructure and chemical composition of the two meteorites are practically identical, and both meteorites may be classified as medium octahedrites belonging to Chemical Group III A. It is suggested that the name Hart Range be deleted from future meteorite catalogues.

The analytical data for a siderite associated with the Wolf Creek crater confirms that it is a member of Chemical Group III B, and it is therefore chemically distinct from the other 3 meteorites. The Wolf Creek crater was therefore a separate event. The uniqueness of the event which formed the Henbury crater is more difficult to establish, as the microstructure and compositional data is very similar to that of the Boxhole meteorite. It is also a medium octahedrite, belonging to Chemical Group III A. However the separation in location of the two craters, small dissimilarities in microstructure, and more particularly the differences in nickel, iridium, copper and zinc abundances, confirm the conclusion of Wasson (1967 a) that Henbury is not associated with the Boxhole meteorite fall.

Acknowledgements.—I would like to thank Dr. B. Mason for his suggestion to investigate the relationship be-

tween the Hart Range and Boxhole meteorites. The meteorite specimens were kindly supplied by the Western Australian Museum Board. I. D. Abercrombie, W. W. Thomas and D. J. Vowles provided technical assistance in some phases of the project.

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